THE STRUCTURAL EVOLUTION OF NAVAL AIR SQUADRONS

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THESIS

THE STRUCTURAL EVOLUTION OF NAVAL AIR SQUADRONS

by

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The Structural Evolution of Naval Air Squadrons

by

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ABSTRACT

Five consecutive years in the evolution of nine U.S. Navy air squadrons were studied to determine the effects of organization size on complexity. Path analysis was used to examine hypothesized causal relationships. Size was found to be less influential than had been expected. The longitudinal approach presented different views of the same organization depending on the variables observed and the time between measurements.

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I. INTRODUCTION

A. BACKGROUND

Empirical studies of formal dimensions of organization structure have been done to analyze relationships between factors that lead to increases in organization complexity (Blau and Schoenherr, 1973; Blauner, 1964; Child, 1973; Hickson, et al., 1969; Samuel and Mannheim, 1970; Woodward, 1965). These investigations have attempted to develop a set of hypotheses that are sufficiently generalizable to become the basis for constructing formal theories of organization. Each of these studies has used sample organizations of varying size, composition, technology, and geographical location to identify factors that related to changes in complexity.

Two variables that have been examined extensively in the literature are organization size and complexity. Causal inferences relating these two variables to structure have been constructed largely from data of cross-sectional research designs. While cross-sectional designs have been useful in dealing with rival hypotheses and in establishing covariance, they cannot establish causality. Longitudinal data collection designs are necessary to discover causal relationships between organization size and complexity, because longitudinal studies account for the time order of these elements.

Meyer (1972), in a study of the administrative structures of 194 departments of finance in city, county, and state governments, compared survey data from the same organizations collected in 1966 and 1971. Hendershot and James (1972) used Office of Education data on 299 school

districts collected at two points in time. Haire (1959) examined case histories of four organizations in a longitudinal study of growth at five points in time. Moore (1974) examined a California Unified School District across 70 years. However, organization structure has not been studied in a research design spanning several years and several organizations concomitantly.

B. LITERATURE ON THE CHARACTERISTICS OF BUREAUCARACIES

1. Longitudinal Studies Involving Size and Structural Differentation

Haire (1959) used a biological analogy to relate size and complexity in the regulation and description of organizational growth. He noted that in solid geometry, volume increases as the cube of a linear measurement, while the surface enclosing it increases by the square of that same measurement. (e.g. for a sphere, $V = 4/3\pi r^3$, and $S = 4\pi r^2$). Haire then hypothesized that as an organization grows, the internal structure (volume) needed to support internal coordination grows faster than overall size (surface), eventually consuming a disproportionately large part of a firm's productive capacity. His results indicated that the percentage of staff increased with size, up to some point, and then stabilized.

McWhinney (1965) reexamined Haire's data and concluded that there was no evidence to support the square-cube biological growth analogy, and Hendershot and James (1972), using their school district data at two points in time, found a general negative relationship between size and the administration-production ratio.

Meyer (1972) used path analytic techniques on several government departments of finance in 1966 and 1971 and found the effects of size on number of subunits, levels of hierarchy, and number of supervisors to

be ubiquitous. Other parameters of organizations had almost no effect on size. The effects of size were greatest on parameters which managers could most easily manipulate. Additionally, apparent relationships among parameters other than size vanished when size was controlled as an influencing variable.

2. Cross-Sectional Studies of Size and Structural Differentiation

Neither complexity nor formalization can be predicted from knowledge of organization size according to Hall (1967).

Klatzky (1970) used two models to explain the relationship between the organization size and the percentage of staff personnel. His regression model indicated that the effect of size was partially dependent on the complexity of an organization; his logarithmic model indicated that increasing size decreased the staff component at a decreasing rate, and explained slightly more variance than the regression model. Klatzky favored the regression model, reasoning that, although the logarithmic model provided a slightly better fit to his data, it was not as firmly couched in theory as the regression model, and therefore did not explain the social process nearly as well.

Blau (1970) and Blau and Schoenherr (1971) analyzed the effects of several formal characteristics of structure across 53 employment security agencies, 387 component divisions, and 1201 local offices of these agencies. Their results indicated that size had a positive relationship to differentiation and administrative overhead among both the agencies and the agencies subunits. But, Blau and Schoenherr reasoned that since the large organizations had a greater structural division of labor, the greater size was related to more and larger structural components. They suggested that an increase in organization size

generates structural differentation, and indirectly raises administrative overhead. On the other hand, the administrative ratio decreased with increases in organizational size despite the increase in the administrative ratio resulting from differentiation in large organizations. They concluded that the relationship between size and other structural variables was nonlinear.

The Aston group's multidimensional approach (Pugh, et al., 1968, 1969) suggested that only four orthogonal dimensions were needed to describe the structure of any work organization. These were defined as (a) structuring of activities, which encompasses specialization, standardization, formalization and vertical span; (b) concentration of authority, encompassing centralization, percentage of line managers, and standardization of personnel procedures; (c) line control of work flow; and (d) relative size of supportive component. Pugh and his associates argued that the independence of these first two dimensions implies that Weber's association of structuring with decentralization is no longer useful for describing organizational processes. Later, (1969) they argued that interactions among independent structural elements allow organizations to bureaucratize along several dimensions.

Child (1972) replicated the Aston study, confirming an association between specialization, standardization of procedures, vertical span, and formalization expressed by the structuring of activities concept. But Child found that centralization of decision making was negatively related to structuring in a way that supported Weber's (1946) description of the bureaucratic mode of administrative control.

Child (1973) compared size-complexity regressions across different industires and found that size, technology, location, and

environmental variables all predicted organization complexity. The degree of complexity had more direct relationship with formalization of procedures than it did with size. In fact, complexity was a critical factor in understanding organization structure but was not more significant than size as a determining factor of structure within the organization.

Reimann (1973) supported the Aston group's multidimensional approach to organization structure. In a factor analysis of data from 19 U.S. manufacturing firms in connection with the structural scales developed by Pugh, et al. (1968), Reimann found three independent dimensions of structure: decentralization, specialization, and formalization.

Mansfield (1973) reviewed the Aston group's methodology and concluded that the main variables in their research were scalar (magnitude and direction) quantities, as they had suggested. The relationship between bureaucratization and centralization of decision making was found to be weak; however, both of these variables were affected by size.

3. Summary of the Literature

Predictions from cross-sectional studies of causal relationships between size and complexity as two dimensions of organization shape have been conflicting. For example, Blau and Schoenherr found that complexity increased at declining rates with increases in size; Hall (1967) found that knowledge of an organization's size did not lead to knowledge of its complexity; and Klatzky (1970) postulated that the effect of size was dependent on the level of complexity.

Studies by the Aston group, using their multidimensional approach, concluded that size and complexity move together, but are subsumed in the context of an organization which, actually determines organization shape. Child (1973), confirmed the Aston group's finding that size predicted complexity, but concluded that complexity interacts more with formalization than size to predict structure.

Longitudinal studies have also drawn different conclusions from empirical data about the effects of size and complexity on structure. While Haire (1959) concluded that as size increased over time, complexity increased in the form of a disproportion of resources allocated to staff and clerical postions, Hendershot and James (1972) suggested a negative relationship between size, growth, and the administration-production ratio. Meyer (1972) found the effect of size on other structural variables to be pervasive. The reason underlying different interpretations of the empirical data may be found in the different analytic techniques applied to the date, and in the research designs themselves.

Structural determinates of organizations have been treated in the literature at one of two points in time, or at several points involving only one organization. In so much as size, complexity, and other variables may interact differently in different organizations; and to the extent that the variables unfold across time as a process, the analysis of data from many organizations taken at numerous intervals across several years should improve empirical results.

This study used the path analysis technique to analyze data gathered from nine separate organizations taken at one year intervals over a period of five years. The objective of the study was to analyze and document the effects of size on complexity on several

organizations across time. Specifically, the proposition to be tested was that complexity is positively related to size. Complexity was operationalized by administrative-production ratios of roles and personnel. Size was operationalized by the total number of people in each organization.

II. METHODOLOGY

A. THE SAMPLE

Data for this study was gathered from nine U.S. Navy Air Squadrons based either on the West Coast of the U.S. or with the Pacific Fleet during the years 1966-1973. These squadrons were under the operational command of Commander, Naval Air, Pacific. All squadrons in the sample were engaged in combat, patrol, or transport activities.

The total personnel assigned to squadrons for each year are shown in Table I.

B. DESIGN OF DATA COLLECTION

Navy organizations submit annual organizational historical records to various administrative commanders. Until 1966, historical summaries were a single page form report that did not contain data suitable for this study. The form report was discontinued in 1966, and organizations then submitted narrative accounts, sometimes accompanied by supporting data. The narrative histories of more than 100 squadrons from each of the eight years 1966 - 1973 were examined at Deputy Chief of Naval Operations - Air Historian Office (DCNO-Air) in Washington, D.C. Nine squadrons had submitted annual histories suitable for the purposes of this study.

The archival histories were used to construct organization charts for each year of available data for each squadron. Squadron commanders generally rotate every two years, thus forming an opportunity for complete reorganization of the squadron at a new commanding officer's

TABLE I

Size of Organizations Versus Time

	1969	1970	1971	1972	1973
Squadron 1	1344	1114	993	844	763
Squadron 2	335	382	374	332	313
Squadron 3	141	128		167	170
Squadron 4	266	271	253	237	253
Squadron 5	181	292	226	221	247
Squadron 6	307	280	261	216	250
Squadron 7		385	330	345	337
Squadron 8		535	268	263	366
Squadron 9		345	341	352	369

discretion, however, no periodic reorganizations were found. Figure 1 shows a chart from a sample year, and Figure 2 is a sample coding sheet.

A list of officer positions was prepared for each year indicating the number of people in each job. The positions were further classified as "direct" or "support" roles. Maintenance and mission type roles were considered "direct" roles. All others were defined as "support" roles. Data was used to define the following three variables:

SIZE = total number of people in the organization

$$\text{People ratio (PR)} = \frac{\text{(Administrative people)} + \text{(Command people)}}{\text{(Operations people)} + \text{(Maintenance people)}}$$

$$\text{Role ratio (RR)} = \frac{\text{(Administrative roles)} + \text{(Command roles)}}{\text{(Operations roles)} + \text{(Maintenance roles)}}$$

These ratios were thought to be representative measures of organizational complexity. By examining the effects of SIZE on PR and RR, the effects of SIZE on complexity could be studied.

C. ANALYSIS STRATEGY

Path analytic techniques as described by Heise (1970) were used to study SIZE, PR, and RR relationships across time. Lagged relationships between SIZE and other variables of one year and two years were examined.

Each variable was examined in terms of (a) direct effects, (b) indirect effects, and (c) total effects of antecedent variables. Direct effects are those resulting from a causal, or independent, variable acting directly on a dependent variable. Indirect effects are those which result when the causual variable acts through an intervening variable on the dependent variable. Total effects are the arithmetic sum of indirect effects and direct effects on a given dependent variable.

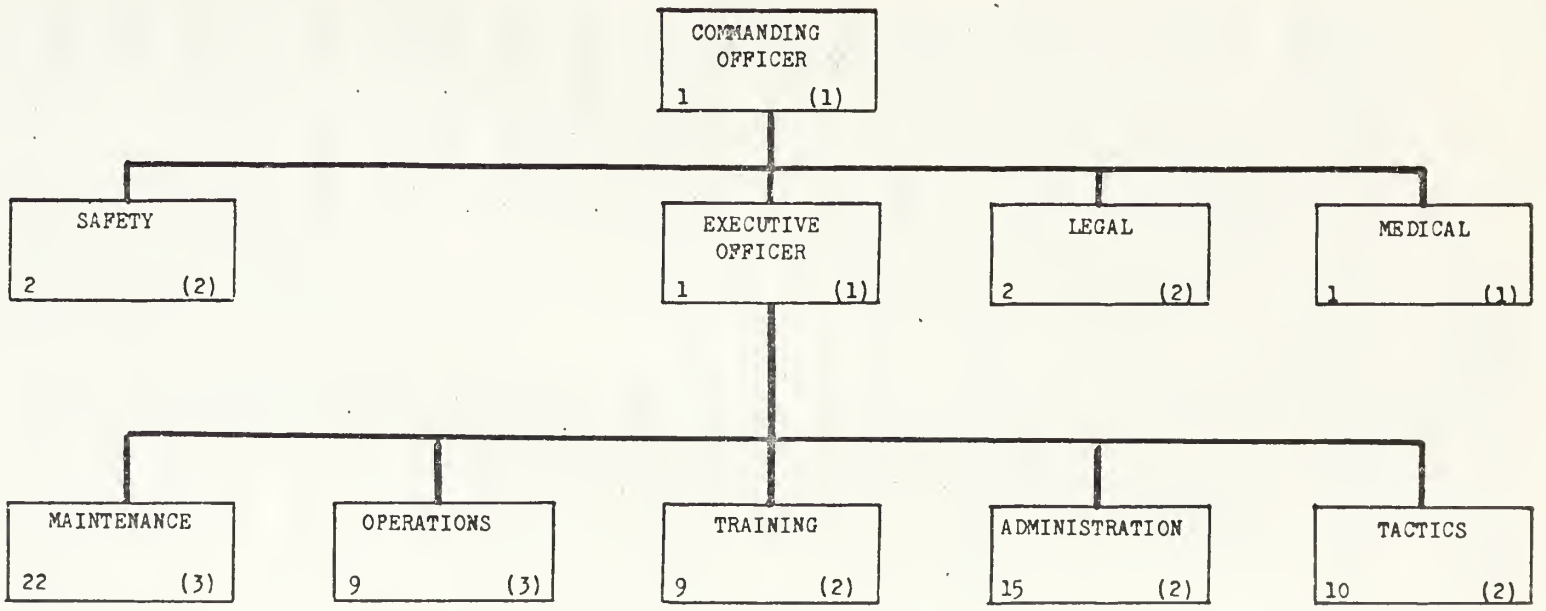

Figure 1

SAMPLE ORGANIZATION CHART

SAMPLE CODING SHEET

Figure 2

Squadron	VP22
Year	72
War in progress	1 (yes)
Unit in war	0 (no)
Span of control	4
Total enlisted	0260
----------Officers only----------	
Command roles	005
Admin roles	002
Ops roles	006
Maint roles	002
Total roles	015
Command people	007
Admin people	015
Ops people	028
Maint people	022
Total Officers	072
Pilots	066
Size72	332
PR72	0.440
RR72	0.875

III. EMPIRICAL FINDINGS

Figures 3 and 4 show the significant paths. Tables II - VIII show the values for the given variables.

A. COEFFICIENTS AFFECTING PR

The direct effects of SIZE on PR were uniformly small in magnitude. With the exception of the 0.22 coefficient associating SIZE69 with PR71, all direct path coefficients were less than 0.1.

The indirect effects, supposedly acting through another variable and subsequently on PR, were generally larger in magnitude, though not uniformly so.

The overall effects of SIZE on PR were, in every case, negative, indicating an inverse relationship between SIZE and PR.

B. COEFFICIENTS AFFECTING RR

The direct effects of SIZE on RR were generally small in magnitude and more or less random in sign, indicating no direct pervasive relationship between the two variables.

The indirect effects of SIZE on RR were generally larger in magnitude than the direct effects and almost totally negative in sign, indicating that if SIZE were related to RR it was through PR rather than directly, and that the relationship was, in every case, an inverse one.

The total effect of SIZE on RR was negative, indicating an inverse overall relationship between SIZE and RR.

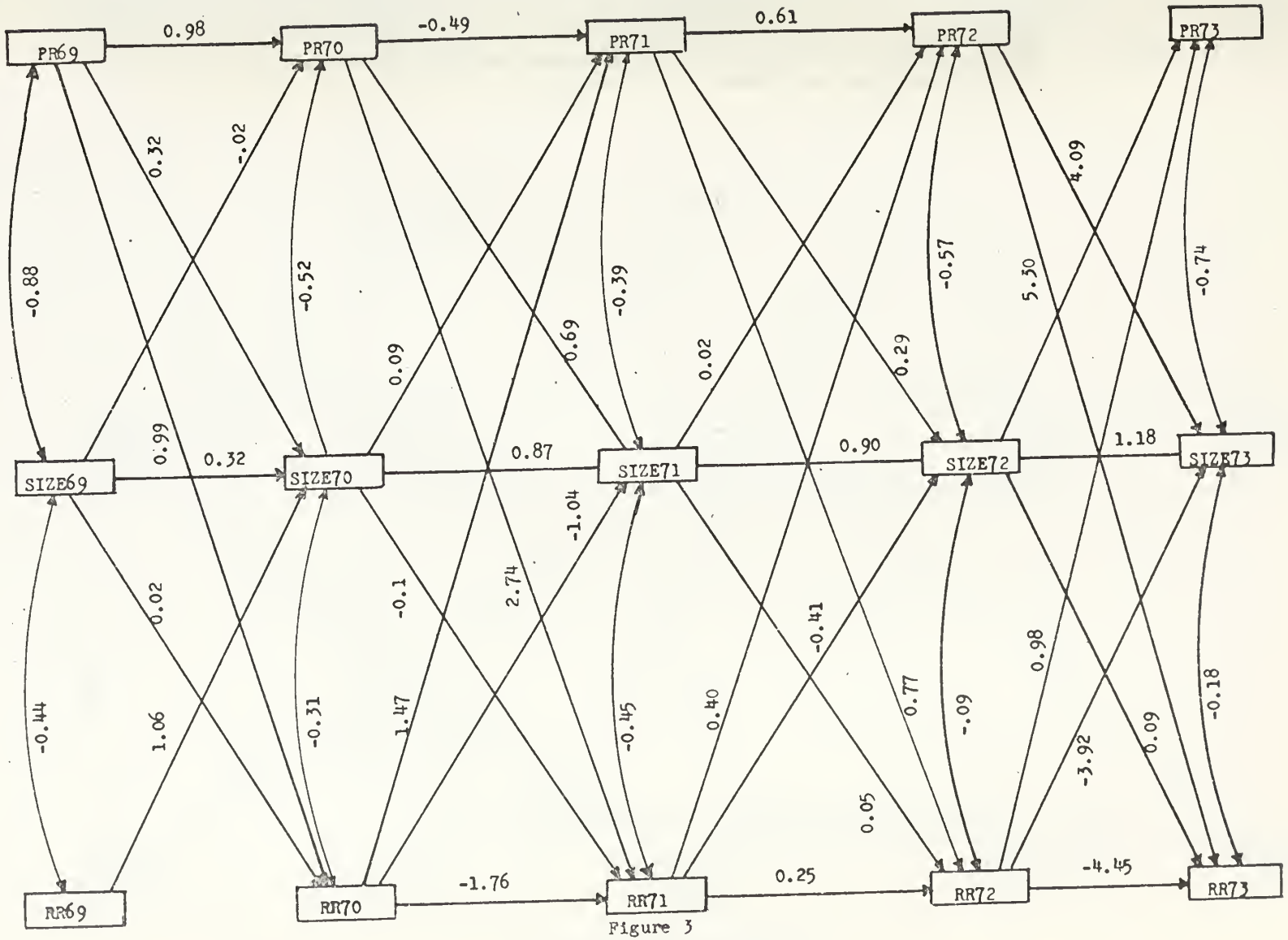

Figure 3

ONE YEAR PATH COEFFICIENTS

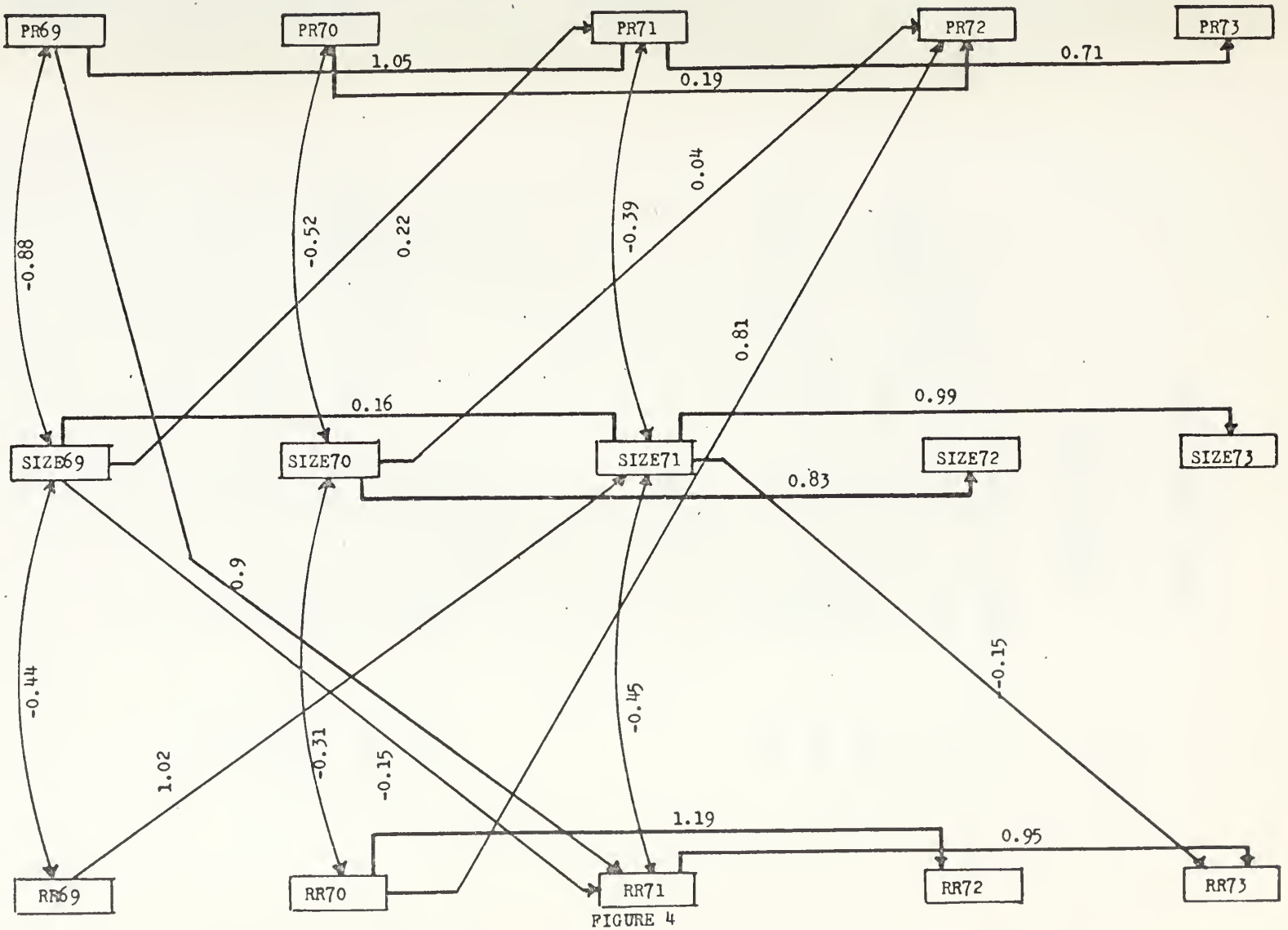

FIGURE 4

TWO YEAR PATH COEFFICIENTS

PATH COEFFICIENTS

1969 - 1970

	PR	SIZE	RR
Direct effect of SIZE	-.02	.32	.02
Indirect effect through: PR	.98	-.28	-.87
RR		-.47	
Total Effect	-.88	-.43	-.85

TABLE II

1970 - 1971

	PR	SIZE	RR
Direct effect of SIZE	.09	.87	-.10
Indirect effect through: PR	.25	-.36	-1.42
RR	-.46	.32	.55
Total Effect	-.12	.83	-.97

TABLE III

PATH COEFFICIENTS

1971 - 1972

	PR	SIZE	RR
Direct effect of SIZE	.02	.90	.05
Indirect effect through: PR	-.24	-.11	-.30
RR	-.18	.18	-.11
Total Effect	-.40	.97	-.36

TABLE IV

1972 - 1973

	PR	SIZE	RR
Direct effect of SIZE	-.05	1.18	-.09
Indirect effect through: PR		-2.33	-3.02
RR	-.09	.35	.40
Total Effect	-.14	-.80	-2.71

TABLE V

PATH COEFFICIENTS

1969 - 1971

	PR	SIZE	RR
Direct effect of SIZE	.22	.16	-.15
Indirect effect through: PR	-.92		-.79
RR		-.45	
Total Effect	-.70	-.29	-.94

TABLE VI

1970 - 1972

	PR	SIZE	RR
Direct effect of SIZE	.04	.83	.09
Indirect effect through: PR	-.10		
RR	-.25		-.37
Total Effect	-.31	.83	-.28

TABLE VII

PATH COEFFICIENTS

1971 - 1973

	PR	SIZE	RR
Direct effect of SIZE		.99	-.15
Indirect effect through: PR	-.28		
RR			-.43
Total Effect	-.28	.99	-.58

TABLE VIII

C. COEFFICIENTS AFFECTING SIZE

The direct effect of SIZE on SIZE of the following years was, as expected, positive and large in magnitude, indicating that future year SIZE is directly related to present year SIZE.

The indirect effect of SIZE on SIZE of following years was generally small in magnitude, indicating a weak relationship between those variables. The indirect effect show no clear tendency toward positive or negative sign; however, in the case of SIZE70 and SIZE73 the indirect effect was noticeably negative.

The total effect of SIZE on SIZE of following years was positive except in the case of SIZE70 and SIZE73. In those years the negative indirect effect was sufficient in magnitude to drive the total effect negative, indicating an inverse relationship between SIZE69 and SIZE70, and between SIZE72 and SIZE73. These results were unexpected.

D. SUMMARY

The total effect of SIZE on the dependent variables was negative for every year in the case of both PR nad RR, indicating an inverse relationship between SIZE and organizational complexity. In two years (69 and 72), SIZE was unexpectedly found to be inversely related to SIZE of the following year, according to path coefficients. Also, path coefficients indicated that considerable effects were due to SIZE acting through intermediate variables instead of directly as was expected.

IV. INTERPRETATION OF THE FINDINGS

The purpose of this study was to determine the effect of organization size on complexity. Size and variables representative of complexity were examined across nine separate organizations measured at one year intervals for five consecutive years.

A. RESERVATIONS IN INTERPRETING PATH COEFFICIENTS

The use of path analysis entails considerable qualification where inferences are drawn from path coefficients based on panel data. Path coefficients are not indicative of causality, but are secondarily reflective of relative magnitude and direction of the effect when causality is assumed. Inferring causality from large path coefficients constitutes a major pitfall of the technique. Ignoring hypothetical variables[1] and subsequently attributing their effect to the variable of interest can also hamper the usefulness of path analysis by introducing exogenous variables via their effect while assuming away their causal existence. Specifically, if any hypothetical variable correlates with the assumed causal variable, the disturbance assumption[2] is violated, and inferences are actually on the causal pair. Separation of the pair requires that they be statistically uncorrelated.

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[1] Hypothetical variables include all those which are not considered in the analysis.

[2] The disturbance assumption is that no hypothetical variable is correlated with any variable in the analysis.

B. INTERPRETATION

It was expected that SIZE would be autocorrelated, and that the direct effect would be at least near the magnitude of the indirect effect, if not larger, for PR and RR.

To the extent that SIZE was not directly related to itself, and direct effects were smaller than indirect effects, the presence of a causal variable other than SIZE is indicated. For instance, it can be reasoned that increases in workload will tend to drive administration-production ratios downward, given constraints on total SIZE. Also, Mayhew (1972) made the assumption that military organizations experienced personnel shortages due to their lack of competetive edge with private industry. The organizations in this study can be assumed to have experienced such shortages for the same reasons, and also because few people, even within the military, volunteered for duty in Viet Nam. With the additional consideration that 1969 - 1972 was a time of increasing U.S. involvement in Viet Nam, and therefore increasing workload for the organizations in this study, a need for examining workload as a causal variable is evident.

Meyer (1972) argued that organizational structure was largely a function of size and that other variables affected neither size nor one another. Meyer's single wave (1966 - 1971) longitudinal study supported that argument; however, the present four wave (69 - 70, 70 - 71, 71 - 72, 72 - 73) longitudinal study has detected considerably smaller perturbances than would have been discovered using only two widely separated time points. The data show that large path coefficients are not confined to size, but in several instances appear between variables other than size.

This study also indicates that the effects of size are not ubiquitous in the case of administrative-production role ratio or people ratio. Additionally, the inconsistent effects of size upon itself lead this researcher to postulate an unmeasured variable, the effects of which were not studied here or by Meyer (1972). That variable is workload.

It has been reasoned that SIZE is somewhat more constrained in military organizations than in civilian industrial organizations. Workload, however, is subject to large fluctuations, both in industry and the military. Assuming that the effects of size or other variables do not violate the constancy assumption[1], and correcting for increasing versus decreasing size, inconsistencies in the year-to-year path coefficients (magnitude or size) could be attributed to workload if appropriately signed and time related. This could account for the effect on SIZE70 and SIZE73 in this study, for instance. Lacking further data, a conclusion to that effect is not possible.

Meyer used his substantive argument that "size is ubiquitous" (1972) to lend credence to a methodological argument that longitudinal data are required to assess the impact of size on other organizational variables or relationships among organizational variables when size was controlled. Nothing in this study is meant to refute that argument. Rather, this researcher would argue that longitudinal data are necessary and furthermore, that the magnitude of detectable effect is directly related to the time between measurements. For example, data from measurements taken

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[1] The constancy assumption is that the causal relations in the system operate continuously and that the structure of the relationships does not change with time. (Heise, 1970)

several years apart might show only gross effects of large underlying causal variables, while data from more closely spaced measurements would expose more intricate relationships. Extrapolating to the limit of infinite measurements, all relationships could be uncovered. Extrapolating to only one measurement, only the static, sociological "balance sheet" relationships could be seen.

V. CONCLUSIONS

This study represents an attempt to contribute to the construction of comprehensive, formal theory of organizations by using path analytic techniques to examine longitudinal panel data. The researcher believes that a contribution has been made, but that it lies in pointing out the road most likely to lead to a formal theory rather than illuminating the formal theory, itself.

A. LIMITATIONS OF PATH ANALYSIS

The path analytic technique is limited in that it entails numerous assumptions concerning the data and it is not a vigorous guide to causality.

Heise (1970) names eleven separate assumptions implicit in the use of path analysis under the categories of assumptions involved in linear regression; assumptions referring to the generality of causal dyanmics; assumptions about the timing of causal effects and measurements; and assumptions concerning extraneous sources of variance. Some of the assumptions are so restrictive that it is doubtful if any sociological variables satisfy them in a rigorous sense. To the degree that variables deviate from the assumptions, the theoretical purity of conclusions from the results of path analysis is limited. Since conclusions include causality, the temptation is great to ignore limitations inherent in the assumptions. Researchers should not yield to that temptation.

B. LONGITUDINAL VERSUS CROSS-SECTIONAL APPROACH

The longitudinal approach is limited only by the amount of data available. It offers virtually unlimited extrapolation so long as times between measurements can be reduced, and it offers not only the posibility of discovering a process as it unfolds, but also after it has unfolded. Where the longitudinal approach is compared with the cross-sectional approach, the analogy of a movie compared to a photograph is helpful. Indeed, the movie is but a series of photographs, but when many sequential photographs are viewed in quick succession the essence of movement is captured. Understanding of organizations will come from examination of dynamic data together with cross-sectional data, not from the limited view offered separtely by either.

C. SIZE-COMPLEXITY RELATIONSHIP

Another form of tunnel vision is studying only variables within the organization. The determination of structural evolution, especially, may be more a function of external variables than internal ones. In this study for example, size was examined as a causal variable and found to be less influential than expected. Analysis of data in this study does not support the proposition that complexity is positively related to size. Having been present as observer and participant in the evolution of some of the organizations studied, the researcher believes that workload may have been more influential in these cases than size. Due to the shoratage of manpower, it was necessary to assign several roles to a single individual in many instances. Thus, a single man might fill the roles of Personnel Officer, Awards Officer, Data Analysist Officer, and Coffee Mess Officer. Although workload was suggested as one possible causal variable, the formulation of more comprehensive theory will

require study of numerous outside variables. In fact, it will require examination of every variable whose impact is significant.

One variable that may have less impact on organizational structure than previous studies have indicated, is size. The researcher cannot but observe that, although some longitudinal studies may involve too few measurements taken at longer than optimum intervals, other longitudinal studies may take too many measurements at shorter than necessary intervals. Just as Meyer's (1972) findings about size disappeared with shorter intervals, so other findings could appear anew with longer intervals. This line of reasoning leads to the observation that relationships among structural variables of organizations may seem to change, depending on how and when they are observed. For example, a news journalist and a historian may have quite different insights and understandings of the same events, but both views are necessary to understand the news events fully. Similarly, both cross-sectional and longitudinal studies are necessary to develop the basis for truly comprehensive theories of organizational development.

D. PRACTICAL APPLICATIONS

Although knowledge and understanding gained from studying Navy air squadrons is not generally applicable to organizations in the rest of the world, specific insights and certain extrapolations can be adapted to serve practical managers. The reason is that air squadrons are like many other organizations in many ways. For instance, air squadrons work in generally high technology fields like computer corporations, airlines, electronics firms, or aircraft manufacturers. Air squadrons require maintenance compatible with quick-reaction service like ambulance services, auto rental agencies, and hospitals. Air squadrons work with

constant personnel shortages like the medical profession, technical firms, and most government agencies. And air squadrons work within budget constraints like almost every other organization.

The researcher cannot know what use individual managers will be able to make of these findings, but it is evident that knowledge of the relationships between size and the number of people or roles devoted to administrative/production functions is relevant. Whether management uses the information to project personnel needs, or to plan a budget, or to compare one organization with another, the result should be more knowledge about the organization's structural evolution. With knowledge of how he got where he is, perhaps the alert manager can make more intelligent decisions as to how to get where he wants to go.

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